Absence of proximal neck dilatation and graft migration after endovascular aneurysm repair with balloon-expandable stent-based endografts

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Objective: **Proximal neck dilatation (PND) and/or endograft migration with the subsequent development of type I endoleak is a significant cause of late endograft failure after endovascular abdominal aortic aneurysm repair (EVAR). Although there are numerous reports examining PND in patients receiving endografts that use self-expanding stents (SES) for proximal fixation, there are no such reports for patients treated with endografts that use balloon-expanding stents (BES). The purpose of this study was to investigate PND and endograft migration after EVAR with BES endografts.**

Methods: **We retrospectively reviewed all charts and all serial computed tomographic scans available for patients who underwent EVAR with a BES endograft (surgeon-made, aortounifemoral polytetrafluoroethylene graft with a proximal Palmaz stent) between August 1997 and October 2002. Only patients with longer than a 12-month follow-up were analyzed. Neck diameter was measured at the level of the lowest renal artery and at 5 mm below it. PND was defined as neck enlargement of 2.5 mm or more. To assess endograft migration, the distance between the superior mesenteric artery and the cranial end of the BES was measured. Stent migration was defined as a change of 5 mm or more.**

Results: **A total of 77 patients received this device during the study period. The technical success rate was 99%. The 1-, 3-, and 5-year survival was 66%, 48%, and 29.5%, respectively. Complete serial computed tomographic scans were available in 41 of the 48 patients who survived 12 months or longer after the operation. The mean follow-up period for these patients was 31 months (range, 12-66 months). The maximum aneurysm diameter was either unchanged or decreased in 35 patients (85%). The immediate postoperative proximal neck diameter was 19 to 29 mm (median, 24 mm). This was unchanged at the latest follow-up. None of the patients had significant PND. The cranial end of the BES was located in the area between 14 mm proximal and 36 mm distal to the superior mesenteric artery (median, 6 mm). None of the patients developed significant endograft migration.**

Conclusions: **Neither PND nor endograft migration was observed with the BES endograft. The nature of the SES may be responsible for the observed neck dilatation and device migration after EVAR with SES endografts. This study suggests that BES may be a better fixation method for EVAR. (J Vasc Surg 2005;42:639-44.)**

Endovascular abdominal aortic aneurysm repair (EVAR) has gained popularity over the last decade. It has proven to be effective in preventing rupture.[1-3] The initial reports showed operative mortality similar to that with open repair.[4-6] However, more recent prospective randomized data from the EVAR 1 and Dutch Randomized Endovascular Aneurysm Management "DREAM" trials showed significant reductions in operative mortality in favor of the endovascular repair.[7] The reduction in morbidity is remarkably pronounced with EVAR.[1,2,8-10] Since its introduction in the early 1990s by Parodi et al,[11] EVAR has undergone significant refinement in devices and operative techniques. However, there continues to be a 10% to 20% reintervention rate, most of which is secondary to endoleak and graft migration resulting in sac expansion.[12-14] Postoperative neck enlargement has been reported in 10% to 36% of cases.[15-23] Loss of proximal fixation will result in graft instability and possible migration and endoleak. There are two different types of endovascular grafts: self expandable and balloon expandable. The former is more common. All previous studies have reviewed proximal neck dilatation (PND) and graft migration after EVAR with self-expanding stent (SES) endografts. This study evaluates PND and graft migration after EVAR with balloon-expanding stent (BES) endografts.

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Competition of interest: Drs Parodi, Veith, and Ohki are major shareholders of the Vascular Innovation, which is a derivative of the MEGS.

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METHODS

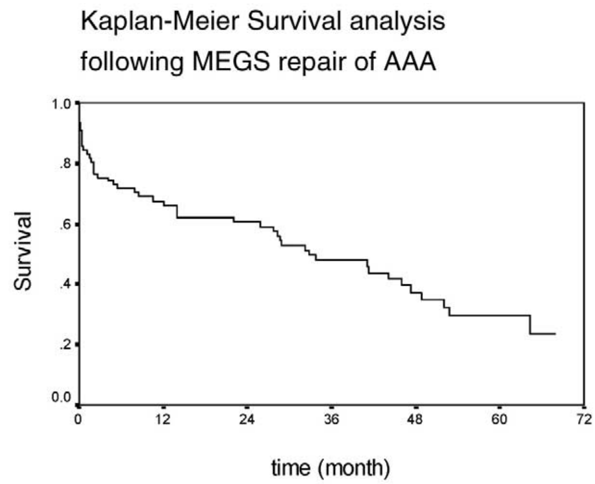
Device. The Montefiore Endografting System (MEGS) has been described elsewhere.[24-26] In brief, the MEGS consists of an aortounifemoral polytetrafluoroethylene graft (IMPRA, Tempe, Ariz) sutured to a proximal BES (Palmaz 5014, 4014; Cordis, Warren, NJ). The proximal end of the graft is predilated with a large balloon to 30 mm in diameter. The stent-graft combination is mounted onto a large angioplasty balloon (Maxi LD; 25 mm × 4 cm;

Cordis). The balloon–stent graft complex is inserted into a 16F sheath (Cook Inc, Bloomington, Ind). The MEGS was used under an investigator-sponsored investigational device exemption approved by the Food and Drug Administration. Institutional review board approval was also obtained. MEGS were used for patients who were not candidates for either open surgery or industry-made endografts. The main reason for exclusion from industry-made endografts was unfavorable proximal neck anatomy, including a highly angulated (>60°) and/or short (<15 mm) neck. In addition, MEGS was preferentially used for ruptured abdominal aortic aneurysms.[24-26]

Techniques. The graft was deployed just below the level of the lowest renal artery. The proximal stent was deployed in the suprarenal area. By varying the inflation pressure of the balloon, the device was able to accommodate a wide range of aortic neck diameters (from 20 to 28 mm). Because the length of the graft was 40 cm, the distal end of the graft always protruded through the ipsilateral femoral arteriotomy and could be cut to accommodate the appropriate length for each patient. An endoluminal handsewn anastomosis was performed to the inside of the distal external iliac or the common femoral arteries. Either a Smart stent (Cordis, Warren, NJ) or a Wall stent (Boston Scientific, Natick, Mass) was deployed in the iliac portion. An occluder device was placed in the contralateral common iliac artery to prevent retrograde perfusion of the aneurysm. A femorofemoral polytetrafluoroethylene bypass was then performed.

Follow-up. Computed tomographic (CT) scans were obtained with intravenous contrast medium. Scans were obtained from 1 cm above the celiac artery down to the femoral arteries. A collimation of 3 mm and a pitch of 2 mm were used to cover the entire anatomic region. Images were reconstructed at 1.5-mm intervals, according to our institutional protocol. No oral contrast medium was used. CT scans were obtained before surgery (except in rupture cases); at 1, 6, and 12 months after surgery; and yearly thereafter. All CT scans were reviewed independently by two vascular surgeons. Comparison was made between the immediate postoperative and latest follow-up scans. Because the purpose of the study was to evaluate the long-term outcome of the MEGS, patients who died within 12 months from the date of the operation were excluded from the analysis.

Measurements. The proximal aortic neck was measured as the outer diameter in the minor axis at two different levels: at the level of the lowest renal artery and 5 mm distal to the first level. Care was taken to consider the tortuosity of the proximal aorta to avoid overestimation of the neck dimension. We defined aortic neck dilatation as an increase in the diameter of 2.5 mm or more. For device migration, the distance from the level of the superior mesenteric artery (SMA) to the CT cut that contained at least one half of the proximal Palmaz stent was measured. We defined graft migration as stent movement of 5 mm or more.



Months	12	24	36	48	60
Patients at risk	48	42	27	15	6
Probability of survival	.6609	.6051	.4803	.3491	.2954
Stander Error	.0542	.0563	.0596	.0631	.0638

	Survival time	Stander Error	95% CI
Mean (month)	34.10	3.20	27.84-40.33
Median (month)	32.75	6.34	20.33-48.18

Fig 1. Kaplan-Meier analysis for one-year, three-year and five-year survival was 66%, 48%, and 29.5%, respectively.

RESULTS

During the study period, 77 patients with abdominal aortic aneurysm underwent a repair with the MEGS. There were 20 women and 57 men. Patient ages ranged between 62 and 92 years (mean, 77 years). Most of the patients had severe comorbidities: 52% had coronary artery disease, 44% had chronic obstructive pulmonary disease, 18% had chronic renal disease, 65% had hypertension, 81% had a long-term history of heavy tobacco smoking, and 8% had diabetes mellitus. Indications[24-26] for using the MEGS instead of the commercially available SES graft were neck angulation greater than 60° (22%), neck diameter greater than 26 mm (10%), neck length less than 15 mm (17%), bilateral iliac involvement (11%), small and or tortuous iliac arteries (32%), and ruptured aneurysm (8%).

The technical success rate was 99%. One patient required conversion to an open procedure, and seven patients (9%) developed endoleak. Type II endoleak occurred in six patients, but none required intervention. Type I endoleak occurred in one patient (1.2%) and necessitated reoperation with deployment of an additional Palmaz stent at the proximal neck. A thrombosed femorofemoral bypass graft necessitating thrombectomy occurred in one patient (1.2%) secondary to transection caused by an incision made for colostomy closure. Graft occlusion developed in six

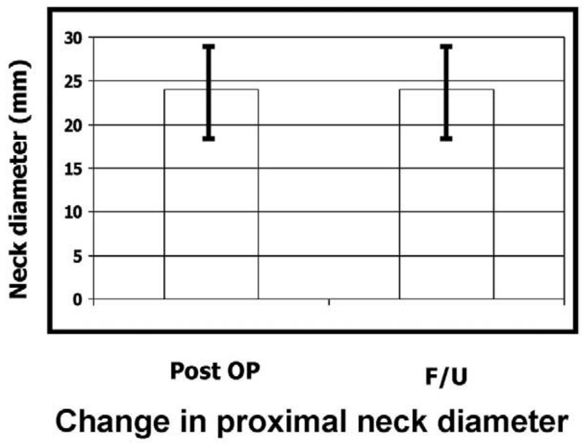


Fig 2. The immediate post-op proximal neck diameter ranging between 19 and 29 mm (median=24 mm), remained unchanged at the latest follow-up. *Post OP,* After surgery; *F/U,* follow-up.

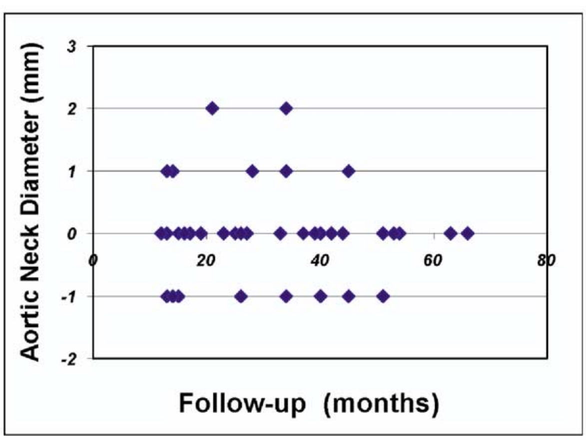


Fig 3. Most of the patients had no change in the PND at the latest follow up. Few patients had 1 mm change and only two patients had an increase of 2 mm in PND.

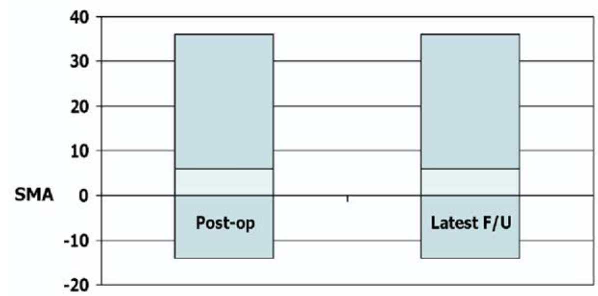


Fig 4. The location of the balloon-expanding stent (BES) remained stable at the latest follow-up. The top of the BES was located in the area between 14 mm proximal and 36 mm distal to the superior mesenteric artery (median, 6 mm). *Post op,* After surgery; *SMA,* superior mesenteric artery; *F/U,* follow-up.

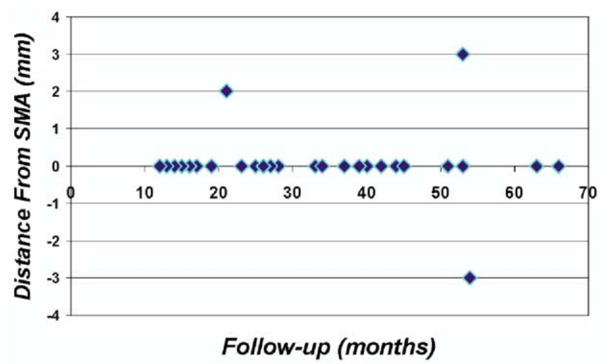


Fig 5. While only three patients had a graft movement of 2-3 mm, none of the patients had true migration of 5 mm or greater.

patients (7.8%); two were treated with thrombectomy, and the remaining four were treated with axillary-bifemoral bypasses. One patient required reoperation for hemorrhage from femorofemoral suture dehiscence. One patient developed a kink in the middle of the graft which was repaired with deployment of a metallic stent. Although no graft infection occurred, two patients (2.5%) had wound infections.

Kaplan-Meier analysis showed the 1-, 3-, and 5-year survival to be 66%, 48%, and 29.5%, respectively (Fig 1). Twenty-four patients (31%) died from cardiopulmonary complications, four patients (5%) died from cancer, and one patient (1%) died secondary to aneurysm rupture. Seven patients (9%) were lost to follow-up. Complete serial CT scans were available in 41 of the 48 patients who survived 12 months or longer after the operation. The mean follow-up period for these patients was 31 months (median, 28 months; range, 12-66 months). More than 60% of patients had longer than 24 months of follow-up, whereas 39% of patients had longer than 36 months of follow-up. The maximum aneurysm diameter was unchanged in 17 patients (41%). In 18 patients (44%), the aneurysm decreased in size. Six patients (15%) had endotension with a significant increase in aneurysm diameter (median, 9.5 mm; range, 5-22 mm), despite the absence of an endoleak. The preoperative mean neck diameter was 23.1 mm (median, 23 mm; range, 18-28 mm). The device was oversized by approximately 5%, making the mean intraoperative PND 1 mm (range, 0.5-2 mm). The immediate postoperative mean proximal neck diameter was 24 mm (median, 24 mm; range, 19-29 mm; Fig 2). This remained unchanged at the latest follow-up (mean, 24 mm; median, 24 mm; range, 19-29 mm). Twenty-six patients (63%) had the same measurement of the proximal neck (Fig 3). Eight patients (20%) had a decrease of 1 mm and five patients (12%) had an increase of 1 mm in the proximal neck diameter. Two patients (5%) had an increase of 2 mm. None had significant PND (≥2.5 mm). The top of the BES (Fig 4) was located in the area between 14 mm proximal and 36 mm distal to the SMA (median, 6 mm). This was

Table. Incidence of PND and graft migration after EVAR with SES grafts

Study	*Device*	*No. patients*	*PND*	*Migration*
Wever[15]	Ancure*	33	10.3% at 6 mo 15.5% at 12 mo	
Makaroun[16]	Ancure	314	13% at 1 y 21% at 2 y 19% at 3 y	
Conners[17]	AneuRx†	81	All patients with migration had significant PND	7.2% at 1 y 20.4% at 2 y 42.1% at 3 y 66.7% at 4 y
Sternbergh[18]	Zenith‡	351	15% at 1 y (<30% graft oversizing) 27% at 1 y (>30% graft oversizing)	0.9% at 1 y (<30% graft oversizing) 14% at 1 y (>30% graft oversizing)
Zarins[19]	AneuRx	1119		2.1% at 1 y 7.2% at 2 y 18.8% at 3 y
Badran[20]	Vanguard§ AneuRx Zenith Talent Stentor Others	73	33% at 2 y	
Cao[21]	AneuRx Excluder‖ Zenith Talent¶	230	28% at 2 y	
Resch[22]	Ivancev-Malmo (aortouni-iliac)	65	22% at 3 y	45% at 3 y
Napoli[23]	AneuRx Excluder Zenith Endologix# Talent Others	90	13% at 1 y 33% at 2 y 36% at 3 y	10.8% at 1 y 18% at 2 y 18.1% at 3 y

*Endovascular Technologies EVT, Guidant (Menlo Park, Calif).
†Medtronics/AVE Inc (Sunnyvale, Calif).
‡Cook Inc (Bloomington, Ind).
§Min Tech (Freeport, Bahamas).
¶W.L. Gore and Associates (Flagstaff, Ariz).
‖World Medical/Medtronics (Sunrise, Fla).
#Endologix (Irvine, Calif).

unchanged at the latest follow-up. The graft remained completely stable (Fig 5) in 38 patients (93%). In two patients (5%), the graft migrated 2 mm. Only one patient (2%) had a 3-mm migration. None had greater than a 3-mm migration.

DISCUSSION

The long-term durability of the endovascular repair of abdominal aortic aneurysms is highly dependent on the integrity of the proximal fixation site. It is known that the infrarenal aortic cuff tends to dilate even after conventional aneurysm repair. This can occur an average of 0.5 mm per year after surgery.[27] The effect of this dilatation is more significant after endovascular repair, because such dilatation may result in the loss of proximal fixation and, possibly, graft migration or endoleak. An increase of 5 mm is considered significant (10% of an average aneurysm size). This is in accordance with the Society of Vascular Surgery reporting standards for EVAR.[28] We used 2.5 mm as a cutoff for significant PND (10% of the average aortic neck diameter). The reporting standards define graft migration as graft movement of 10 mm or more relative to an anatomic landmark. We considered any migration greater than 5 mm to be significant. Most prior studies have used the lowest renal artery as a landmark to monitor graft migration. The reason for use of the SMA as a landmark for migration in this study was that all of our patients had suprarenal fixation with the Palmaz stent. Even with more strict standards, our data demonstrate an impressive 0% dilatation/migration rate. Most grafts available today for EVAR are SES endografts. The short-, mid-, and long-term PND and graft migration after EVAR with these grafts have been studied extensively and are summarized in the Table.[15-23] Because the SES endograft is oversized by 10% to 20% of the preoperative proximal neck diameter at the time of EVAR, it retains its expansive radial force. BES is oversized by 5%. The Palmaz stent will maintain its diameter after the initial deployment dilatation and does not exert any ongoing expansive force. The proximal neck would be exposed to two opposite forces: the recoil force of the elastic aortic wall and the expansive radial force of the proximal endograft stent. If the radial force were greater than the recoil force, as seen with the 20% oversized SES, PND would be imminent. If the recoil force were greater than the radial force, PND would be less likely. This may be partially responsible for the 0% PND in BES in comparison with the observed 10% to 36% PND in SES.[15-23] The documented 1- to 2-mm PND (17% of our patients) is well within the interobserver measurement variability interval.[29] The natural tendency for the infrarenal aorta to dilate (0.5 mm per year)[27] and the 5% intraoperative oversizing of the BES could be additional factors contributing to the minimal neck dilatation observed in our patients.

There is a clear association between PND and migration.[17,22,23] SES endografts migrate at a 10% to 40% rate.[17-19,22,23] Resch et al[22] documented that 50% of patients with migration had significant PND. Napoli et al[23] showed that 35% of the patients with significant PND had graft migration.

In contrast to studies with SES, we did not observe endograft migration. Several reasons may explain these differences. The absence of PND with BES-based endografts is an important factor in preventing migration.[22,23]

Suprarenal fixation is another important factor that might decrease the incidence of migration. Although some authors have shown no significant relation between migration and the type and model of the prosthesis (suprarenal vs infrarenal fixation),[23] others have documented a low incidence of migration (14%) in SES endografts with suprarenal fixation.[18] This incidence is significantly lower than the alarming 40% to 60% migration rates that are documented with some of the infrarenal fixation SES grafts.[17] Suprarenal fixation would decrease migration but would not eliminate it.

The Palmaz stainless-steel stent has minimal recoil and acts as a cylinder against which the elastic aortic wall exerts force. This results in an impressive strength that stabilizes the aortic neck. Resch et al,[30] with a cadaveric model, studied the force required to dislodge a variety of endografts. The Palmaz-based balloon-expandable endograft required more dislodgement force than the Ancure (Endovascular Technologies EVT, Guidant, Menlo Park, Calif), Talent (World Medical/Medtronics, Sunrise, Fla), Vanguard (Min Tech, Freeport, Bahamas), and Zenith (Cook Inc, Bloomington, Ind) endografts, all of which use the SES. This secure fixation may explain the absence of stent migration. In addition, tissue incorporation is minimal with SES endografts. In 2 studies, 29 devices were explanted either at late conversion or at autopsy up to 3 years after implantation.[31,32] All specimens were studied with the highest standards—anatomic, histologic, and biochemical methods of investigation. No evidence of even traces of incorporation of the grafts by the native tissue was found in any of the cases.[33] The lack of tissue incorporation will lead to proximal stent migration in the presence of PND. Conversely, the BES graft with the Palmaz stent strut, well embedded into the aortic wall and actually breaking the internal elastic lamina, stimulates significant inflammation, smooth muscle proliferation, and intimal hyperplasia.[34] This results in aggressive incorporation of the struts within the fibrous tissues.[35] This inflammatory response and tissue incorporation of the BES may have added stability to the graft and prevented future migration.

During EVAR, we have observed micromotion of the SES with fluoroscopy. The SES grafts pulsate with every heartbeat. This repetitive micromotion, which is not observed with the BES, causes a continuous strain on the stent and may be responsible for stent fatigue fractures and PND. For example, Zarins et al[36] studied these structural defects on more than 100 explanted SES grafts. Stent fractures occurred in 66% of the explants. This study showed more stent strut fractures in grafts that showed migration before explantation.

One other factor that may explain the absence of PND and migration in BES grafts is the precision of deployment. This allows maximal coverage of the neck, which could be an inhibitory factor of PND. A few millimeters of uncovered neck left above the SES graft will be prone to future dilatation. Zarins et al[19] showed a clear and direct correlation between graft migration and the distance between the lowest renal artery and top of the stent graft. Each millimeter increase between the renal arteries and the proximal graft fixation site increases the risk for subsequent migration by 5.8%, and each millimeter increase in proximal fixation length decreases the risk of migration by 2.5%.

The Lifepath (Edwards Lifesciences Corporation, Irvine, CA) system is another BES device. The device is no longer available; however, the data are very useful in this discussion. In comparison with the MEGS grafts, this device lacks a suprarenal stent. It uses a stented endoskeleton constructed from Elgiloy. The migration rate was 0% for the second-generation devices.[37] This emphasizes that suprarenal fixation is not the only factor in reducing migration incidence. Both the Lifepath and the MEGS devices are BES, eliminate ongoing radial stress to the aortic neck, and allow more precise deployment, thus resulting in less PND and migration. The importance of PND and graft migration is emphasized in the recent finding that late rupture after EVAR is related to graft migration rather than aneurysm dilatation.[7]

The limitation of this study is the small sample size. This was a group of patients with severe comorbidities and highly complex aneurysms. These patients had a high non–aneurysm-related mortality rate, which further decreased the length of follow-up. However, most of the available data on SES grafts showed a significant PND and migration rate at 1- to 3-year follow-up (Table).[15-23] More than 60% of our patients had more than 24 months of follow-up, whereas 39% of patients had more than 36 months of follow-up.

CONCLUSIONS

Although the sample size is small, this study shows that neither PND nor migration occurs after BES endografting. This observation suggests that BES may be a better platform for endograft fixation, which is the cornerstone for a durable EVAR.

REFERENCES

1. Brewster D, Cronenwett J, Hallett J, Johnston K, Krupski W, Matsumura J. Guidelines for the treatment of abdominal aortic aneurysms report of a subcommittee of the Joint Council of the American Association for Vascular Surgery and Society for Vascular Surgery. J Vasc Surg 2003;37:1106-17.
2. Zarins CK, White RA, Schwarten D, et al. AneuRx stent graft versus open surgical repair of abdominal aortic aneurysms: multicenter prospective clinical trial. J Vasc Surg 1999;29:292-8.
3. Bush LR, Lumsden AB, Dodson TF, et al. Mid-term results after endovascular repair of the abdominal aortic aneurysm. J Vasc Surg 2001;33:S70-6.
4. Feigal D. FDA public health notification: updated data on mortality associated with Medtronic AVE AneuRx stent graft system. US Food and Drug Administration, 2001; website.
5. Arko F, Lee W, Hill B, Olcott C, Dalman R, Harris E, et al. Aneurysm-related death: primary endpoint analysis for comparison of open and endovascular repair. J Vasc Surg 2002;36:297-304.
6. Adriansen MEAPM, Bosch JL, Halpern EF, Hunink MGM, Gazelle GS. Elective endovascular versus open surgical repair of abdominal aortic aneurysms: systematic review of short-term results. Radiology 2002;224:739-47.
7. Greenhalgh RM, Brown LC, Kwong GP, Powell JT, Thompson SG. Comparison of endovascular aneurysm repair with open repair in patients with abdominal aortic aneurysm (EVAR trial 1), 30-day operative mortality results: randomised controlled trial. Lancet 2004; 364:818-20.
8. Anderson P, Arons R, Moskowitz A. A statewide experience with endovascular abdominal aortic aneurysm repair: rapid diffusion with excellent early results. J Vasc Surg 2004;39:10-9.
9. Williamson WK, Nicoloff AD, Taylor LM Jr, Moneta GL, Landry GJ, Porter JM. Functional outcome after open repair of abdominal aortic aneurysm. J Vasc Surg 2001;33:913-20.
10. Lederle FA, Johnson GR, Wilson SE, Acher CW, Ballard DJ, Littooy FN, et al. Quality of life, impotence, and activity level in a randomized trial of immediate repair versus surveillance of small abdominal aortic aneurysm. J Vasc Surg 2003;38:745-52.
11. Parodi J, Palmaz J, Barone H. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg 1991;5:491-9.
12. Ohki T, Veith FJ, Shaw P, et al. Increasing incidence of midterm and long-term complications after endovascular graft repair of abdominal aortic aneurysms: a note of caution based on a 9-year experience. Ann Surg 2001;234:323-35.
13. Schurink GW, Aarts NJ, Bockel JH. Endoleak after stent graft treatment of abdominal aortic aneurysm: a meta-analysis of clinical studies. Br J Surg 1999;86:581-7.
14. Laheij RJ, Buth J, Harris PL, Moll FL, Stelter WJ, Verhoevens EL. Need for secondary interventions after endovascular repair of abdominal aortic aneurysm: intermediate-term follow-up results of a European collaborative registry (EUROSTAR). Br J Surg 2000;87:1666-73.
15. Wever J, de Nie A, Blankensteijn D, Broeders AM, Mali W, Eikelboom B. Dilatation of the proximal neck of infrarenal aortic aneurysms after endovascular AAA repair. Eur J Vasc Endovasc Surg 2000;19:197-201.
16. Makaroun MS, Deaton DH. Is proximal aortic neck dilatation after endovascular aneurysm exclusion a cause for concern? J Vasc Surg 2001;33:S39-45.
17. Conners M III, Sternbergh C III, Carter G, Tonnessen B, Yoselevitz M, Money S. Endograft migration one to four years after endovascular abdominal aortic aneurysm repair with the AneuRx device: a cautionary note. J Vasc Surg 2002;36:476-84.
18. Sternbergh C, Money S, Greenberg R, Chuter T. Influence of endograft oversizing on device migration, endoleak, aneurysm shrinkage, and aortic neck dilation: results from the Zenith multicenter trial. J Vasc Surg 2004;39:20-6.
19. Zarins C, Bloch D, Crabtree T, Matsumoto A, White R, Fogarty T. Stent graft migration after endovascular aneurysm repair: importance of proximal fixation. J Vasc Surg 2003;38:1264-72.
20. Badran MF, Gould DA, Raza I, McWilliams RG, Brown O, Harris PL, et al. Aneurysm neck diameter after endovascular repair of abdominal aortic aneurysms. Vasc Interv Radiol 2002;13(9 Pt 1):887-92.
21. Cao P, Verzini F, Parlani G, Rango P, Parente B, Giordano G, et al. Predictive factors and clinical consequences of proximal aortic neck dilatation in 230 patients undergoing abdominal aorta aneurysm repair with self-expandable stent-grafts. J Vasc Surg 2003;37:1200-5.
22. Resch T, Ivancev K, Brunkwall J, Nyman U, Malina M, Lindblad B. Distal migration of stent-grafts after endovascular repair of abdominal aortic aneurysms. J Vasc Interv Radiol 1999;10:257-64.
23. Napoli V, Sardella SG, Bargellini I, Petruzzi P, Cioni R, Vignali C, et al. Evaluation of the proximal aortic neck enlargement following endovascular repair of abdominal aortic aneurysm: 3-years experience. Eur Radiol 2003;13:1962-71.
24. Ohki T, Veith FJ. Standard and new treatments for abdominal aortic aneurysms: the value of the Montefiore endovascular grafts for difficult aneurysms. Jpn Circ J 1999;63:829-37.
25. Ohki T, Veith FJ. Endovascular grafts and other image-guided catheter-based adjuncts to improve the treatment of ruptured aortoiliac aneurysms. Ann Surg 2000;232:466-79.
26. Ohki T, Veith FJ. Endovascular therapy for ruptured abdominal aortic aneurysms. Adv Surg 2001;35:131-51.
27. Liapis C, Kakisis J, Kaperonis E, Papavassiliou V, Karousos D, Tzonou A , et al. Changes of the infrarenal aortic segment after conventional abdominal aortic aneurysm repair. J Vasc Surg 1998;27:805-11.
28. Chaikof EL, Blankensteijn JD, Harris PL, et al. Reporting standards for endovascular aortic aneurysm repair. J Vasc Surg 2002;35:1048-60.
29. Cayne N, Veith F, Lipsitz E, Ohki T, Mehta M, Gargiulo N, et al. Variability of maximal aortic aneurysm diameter measurements on CT scan: significance and methods to minimize. J Vasc Surg 2004;39: 811-5.
30. Resch T, Malina M, Lindblad B, Malina J, Brunkwall J, Ivancev K. The impact of stent design on proximal stent-graft fixation in the abdominal aorta: an experimental study. Eur J Vasc Endovasc Surg 2000;20: 190-5.
31. Guidoin R, Marois Y, Douville Y, et al. First-generation aortic endografts: analysis of explanted Stentor devices from the EUROSTAR Registry. J Endovasc Ther 2000;7:105-22.
32. Malina M, Brunkwall J, Ivancev K, et al. Endovascular healing is inadequate for fixation of Dacron stent-grafts in human aortoiliac vessels. Eur J Vasc Endovasc Surg 2000;19:5-11.
33. Szilagyi DE. The problem of healing of endovascular stent grafts in the repair of abdominal aortic aneurysms. J Vasc Surg 2000;12:83-5.
34. Schwartz RS, Murphy JG, Edwards WD, Camrud AR, Vliestra RE, Holmes DR. Restenosis after balloon angioplasty: a practical proliferative model in porcine arteries. Circulation 1990;82:2190-200.
35. Sullivan TM, Ainsworth SD, Langan EM, Taylor S, Snyder B, Cull D, et al. Effect of endovascular stent strut geometry on vascular injury, myointimal hyperplasia, and restenosis. J Vasc Surg 2002;36:143-9.
36. Zarins C, Arko F, Crabtree T, Bloch D, Ouriel K, Allen R, et al. Explant analysis of AneuRx stent grafts: relationship between structural findings and clinical outcome. J Vasc Surg 2004;40:1-11.
37. Harris PL, Buth J. An update on the important finding from the EUROSTAR EVAR registry. Vascular 2004;12:33-8.

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